

UNCLASSIFIED

AD NUMBER

AD384474

CLASSIFICATION CHANGES

TO: UNCLASSIFIED

FROM: CONFIDENTIAL

LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited.

FROM:

Distribution authorized to U.S. Gov't. agencies and their contractors;  
Administrative/Operational Use; OCT 1967. Other requests shall be referred to Army Missile Command, Attn: Research and Development Directorate, Redstone Arsenal, AL 35809.

AUTHORITY

USAMICOM ltr dtd 1 Feb 1974 USAMICOM ltr dtd 1 Feb 1974

THIS PAGE IS UNCLASSIFIED

# **GENERAL DECLASSIFICATION SCHEDULE**

**IN ACCORDANCE WITH  
ODD 5200.1-R & EXECUTIVE ORDER 11652**

## **THIS DOCUMENT IS:**

---

**Subject to General Declassification Schedule of  
Executive Order 11652-Automatically Downgraded at  
2 Years Intervals- DECLASSIFIED ON DECEMBER 31, 1972**

**BY**  
Defense Documentation Center  
Defense Supply Agency  
Cameron Station  
Alexandria, Virginia 22314

# **SECURITY**

---

# **MARKING**

**The classified or limited status of this report applies  
to each page, unless otherwise marked.  
Separate page printouts MUST be marked accordingly.**

---

**THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF  
THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18,  
U.S.C., SECTIONS 793 AND 794. THE TRANSMISSION OR THE REVELATION OF  
ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY  
LAW.**

**NOTICE: When government or other drawings, specifications or other  
data are used for any purpose other than in connection with a defi-  
nitely related government procurement operation, the U. S. Government  
thereby incurs no responsibility, nor any obligation whatsoever; and  
the fact that the Government may have formulated, furnished, or in any  
way supplied the said drawings, specifications, or other data is not  
to be regarded by implication or otherwise as in any manner licensing  
the holder or any other person or corporation, or conveying any rights  
or permission to manufacture, use or sell any patented invention that  
may in any way be related thereto.**

**CONFIDENTIAL**

COPY

A. D.

19

Technical Report S-151

AD384474

A COMPARISON OF SELECTED GEMINAL AND VICINAL  
INGREDIENTS FOR USE IN PROPELLANTS (U)

by

J. A. Lovinger

October 1967

U. S. ARMY MISSILE COMMAND  
Redstone Arsenal, Alabama 35809

Contract  
DAAH01-67-C-0655

ROHM AND HAAS COMPANY  
REDSTONE RESEARCH LABORATORIES  
HUNTSVILLE, ALABAMA 35807

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794. The transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

DISTRIBUTION LIMITED  
SEE INSIDE FRONT COVER

D D C  
REFINED  
OCT 18 1967  
RECORDED  
R ✓

**CONFIDENTIAL**

#### DISTRIBUTION LIMITATION

Initial distribution of this report has been made in accordance with contractual agreements and approved supplements received from our Contracting Officer. Qualified users may obtain this report from the Defense Documentation Center, Cameron Station, Building 5, Alexandria, Virginia 22314.

In addition to security requirements which must be met, this document is subject to special export controls, and each transmittal to foreign governments or foreign nationals may be made only with prior approval of:

Department of Army  
Headquarters, U. S. Army Missile Command  
Redstone Arsenal, Alabama 35809

#### DISCLAIMER

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

#### DISPOSITION INSTRUCTIONS

When this report is no longer needed, Department of the Army organizations will destroy it in accordance with the procedures given in AR 380-5. Navy and Air Force elements will destroy it in accordance with applicable directions. Department of Defense contractors will destroy the report according to the requirements of the Industrial Security Manual for Safeguarding Classified Information. All others will return the report to:

Department of Army  
Headquarters, U. S. Army Missile Command  
Redstone Arsenal, Alabama 35809  
ATTN: AMSMI-IYC

DOWNGRADED AT 3 YEAR INTERVALS:  
DECLASSIFIED AFTER 12 YEARS.

**CONFIDENTIAL**

October 1967

Technical Report S-151

**A COMPARISON OF SELECTED GEMINAL AND VICINAL  
INGREDIENTS FOR USE IN PROPELLANTS (U)**

by

J. A. Lovinger

U. S. ARMY MISSILE COMMAND  
Redstone Arsenal, Alabama 35809

Contract  
DAAH01-67-C-0655

**Distribution Limited**

**ROHM AND HAAS COMPANY**

**REDSTONE RESEARCH LABORATORIES**

HUNTSVILLE, ALABAMA 35807

STATEMENT #2 CLASSIFIED

In addition to security requirements which must be met, this document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of *U.S. ARMY MISSILE COMMAND  
REDSTONE ARSENAL, ALABAMA*.

**CONFIDENTIAL**

35809

## FOREWORD

The work described in this report was performed under Contract DAAH01-67-C-0655 for exploratory development of propellants for missiles and rockets. It was part of these Laboratories' program to develop high-energy solid-propellant formulations based on an NF system. The work was under the technical cognizance of the Solid Propellant Chemistry Branch of the Army Propulsion Laboratory and Center, Research and Development Directorate, U. S. Army Missile Command.

The data have been drawn from many sources at these Laboratories. Special thanks are due Messrs. D. W. Booth and E. L. Allen and Dr. A. J. Ignatowski.

**CONFIDENTIAL**

(C) ABSTRACT

This report contains a compilation of data comparing geminal and vicinal difluoramino-containing plasticizers and copolymers. The plasticizers studied are 1,2,3-tris[1,2-bis(difluoramino)ethoxy]-propane and 1,2,3-tris[2,2-bis(difluoramino)propoxy]propane. The copolymers are acrylic acid copolymers of both 2,3-bis(difluoramino)-propyl acrylate and 2,2-bis(difluoramino)propyl acrylate. Data are presented for the monomeric materials, copolymers, binders, and propellants.

The data indicate that the vicinal and geminal materials behave similarly in many respects. The major disadvantage of the geminal NF-containing materials is their greater impact sensitivity. The main area in which the geminal materials show an advantage is seen in those tests related to storage stability. These tests include vacuum gas evolution and adiabatic self-heating. Data on fissuring time show that the geminal copolymers are as good as, if not better than, the best vicinal copolymers made to date. The geminals also have higher burning rates than the corresponding vicinals; however, the increase observed in the propellant is small.

(U) CONTENTS

	Page	
Foreword	iii	
Abstract	iv	
Figures	vi	
Tables	vii	
Section I.	INTRODUCTION	1
Section II.	MATERIALS	3
Section III.	PHYSICAL PROPERTIES OF NF COMPOUNDS	7
Section IV.	GLASS-TRANSITION TEMPERATURE OF NF PLASTICIZERS AND POLYMERS	10
Section V.	MECHANICAL PROPERTIES OF NF PROPELLANTS	11
Section VI.	FISSURING-TIME TEST	14
Section VII.	VACUUM GAS EVOLUTION	15
Section VIII.	ADIABATIC SELF-HEATING RATE	20
Section IX.	DIFFERENTIAL THERMAL ANALYSIS	23
Section X.	THERMOGRAVIMETRIC ANALYSIS	29
Section XI.	SENSITIVITY	33
Section XII.	BALLISTIC PROPERTIES	34
Section XIII.	SUMMARY AND CONCLUSIONS	38
References	39	

(U) FIGURES

1. Infrared Spectra of the Two Monomers
2. Infrared Spectra of the Two Plasticizers
3. Equilibrium Young's Moduli for RH-SE-103 [ V, V] and RH-Y-2 [ G, G]
4. Gas Evolution of NF Copolymers
5. Gas Evolution of Some NF Binders
6. Gas Evolution of Three NF-Containing Propellants
7. Adiabatic Self-Heating Rates for PPAA-4 [ V] and PY-1 [ G]
8. Thermogram of TGAP [ G]
9. Thermogram of RH-Y-2 [ G, G] Propellant
10. Thermogram of NFPA [ V]
11. Thermogram of MY [ G]
12. Thermogravimetric Analysis Curve for RH-SE-103 [ V, V]
13. Thermogravimetric Analysis Curve for RH-Y-1 [ G, V]
14. Strand Burning Rates of Binders
15. Strand Burning Rates for Three NF-Containing Propellants

(U) TABLES

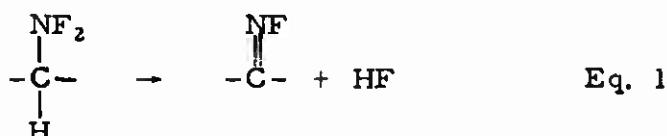
- I. Physical Properties of NF Materials
- II. Selected Viscosities at Various Stages of Formulation
- III. Glass-Transition Temperatures of Geminal and Vicinal Materials
- IV. Stress-Strain Data for Propellants
- V. Equilibrium Young's Moduli for Propellants
- VI. Gas Evolution of Selected Materials at 80°C in cc STP/gm
- VII. Adiabatic Self-Heating Rates of Propellant Materials
- VIII. DTA Temperatures for Vicinal and Geminal Materials
- IX. TGA Data for Geminal and Vicinal Comparison
- X. Comparison of Sensitivity Data of Geminal and Vicinal Materials
- XI. Strand Burning Rates for Propellants
- XII. Ballistic Data Comparing Geminal and Vicinal Copolymer Propellants

**CONFIDENTIAL****Section I. (C) INTRODUCTION**

Over the past several years, Rohm and Haas Company's Redstone Research Laboratories have been involved in an effort to develop propellants containing difluoramino compounds. A recent milestone was the firing of an 80-pound motor containing a binder and a plasticizer each containing difluoramino groups. The binder was a copolymer of 2, 3-bis(difluoramino)propyl acrylate (NFPA) and acrylic acid plasticized with 1, 2, 3-tris[1, 2-bis(difluoramino)-ethoxy]propane (TVOPA). The propellant was a standard composition chosen for detailed study (RH-SE-103).

Early efforts to improve the shelf life of the propellant showed that the products formed by initial dehydrofluorination of the difluoramino compounds could in turn lead to gaseous products (1)<sup>1</sup>. These gaseous products are probably a major cause of the short shelf-life originally measured for this class of propellants as evidenced by fissuring-time and other tests. Much effort has been expended to improve the storage characteristics of RH-SE-103 propellant. Methods of purifying materials have been developed; new processing routes have been devised. Today, based on accelerated aging tests, RH-SE-103 propellants have a projected shelf life about the same as that for composite double-base propellants.

Another way to improve the storage life of difluoramino-containing propellants revolves around the possibility of preventing the decomposition chain of reactions which lead to gas formation. TVOPA and NFPA both have difluoramino groups attached to carbons which are bonded to hydrogens. The dehydrofluorination then can proceed according to Equation 1.



In the geminal compounds studied for this report, there are no hydrogens attached to the carbons to which the difluoramino groups

---

<sup>1</sup> Numbers in parentheses refer to references listed at the end of the report.

**CONFIDENTIAL**

are attached. Thus, there is no easy way to initiate the dehydrofluorination reaction. This resistance to dehydrofluorination by geminal materials is illustrated by the drastic conditions necessary to hydrolyze geminal compounds for analysis as compared with the conditions necessary for vicinal compounds (2).

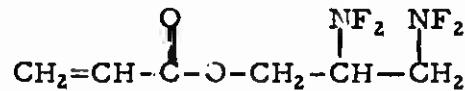
The purpose of this report is to present, in a unified manner, data which can be used to compare directly the geminal and vicinal systems so as to determine areas of further study of geminal materials and to aid in deciding whether further scale-up of geminal production should be made at this time. The report draws on our extensive experience with the vicinal system and gives a selection of some of the "best" current data. For the geminal system, the major work is still on the bench scale; however, a small pilot plant to make geminal monomer has been placed in operation. The preparation of the geminal plasticizer used in this study is still on the laboratory scale. The geminal data are thus based on a minimum of experience and represent the earliest stages of development.

**CONFIDENTIAL**

Section II. (C) MATERIALS

(U) The materials discussed in this report are identified in this section. The symbol used to represent each material is placed in the left margin to aid in later identification.

NFPA      1. (C) 2,3-bis(difluoramino)propyl acrylate (C)



(U) A liquid acrylic monomer which contains vicinal NF<sub>2</sub> groups. Its preparation and some of its properties have been reported (3, 4).

AA      2. (U) acrylic acid

(U) Acrylic acid is copolymerized with NF<sub>2</sub>-acrylates to give cross-linking sites in the copolymer.

PPAA      3. (C) vicinal-NFPA copolymer (C)

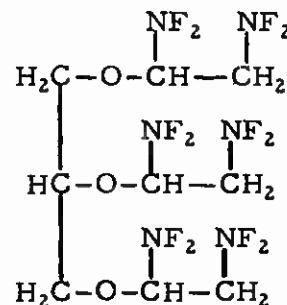
(C) A copolymer of NFPA and AA formed by batch-free radical polymerization. A number following the symbol, i.e., 4 in PPAA-4, indicates a particular copolymer formulation. The polymerization characteristics and some properties of the copolymer system have been described (3).

PPAA-4E    4. (C) incremental-addition vicinal-NFPA copolymer (C)

(C) A copolymer of NFPA and AA formed by free-radical polymerization. Instead of a batch process, the monomers are added in increments during the polymerization (5). This incremental-addition method has led to higher-molecular-weight material, and it is believed that the molecular-weight distribution is narrower than in the case of the simple batch process.

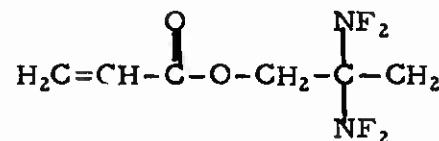
**CONFIDENTIAL**

TVOPA      5. (C) 1, 2, 3-tris[1, 2-bis(difluor amino)ethoxy]propane (C)



(U) A liquid plasticizer containing vicinal  $\text{NF}_2$  groups. Preparation methods have been described (6).

MY      6. (C) 2, 2-bis(difluor amino)propyl acrylate (C)

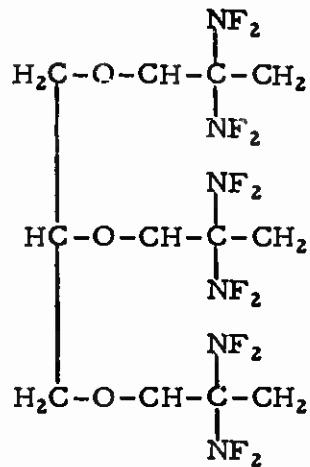


(C) A liquid acrylate containing geminal  $\text{NF}_2$  groups. Synthesis methods are similar to those used for NFPA. The synthesis method for the intermediate has been described (7).

PY      7. (C) geminal-NFPA copolymer (C)

(C) A copolymer formed by the copolymerization of MY and AA. The polymerization characteristics of this system are under study and will be reported shortly (8). Preliminary evidence is that this system polymerizes more slowly than does the NFPA-AA system.

TGAP      8. (C) 1, 2, 3-tris[2, 2-bis(difluor amino)propoxy]propane (C)

**CONFIDENTIAL**

(U) A liquid plasticizer containing  $\text{NF}_2$  groups.  
Its preparation has been described (9).

RH-SE-103 9. (C) vicinal propellant (C)

(C) A standard propellant formulation contained  
the following:

Material	Wt. %
PPAA	13
TVOPA	26
Ammonium Perchlorate	46
Aluminum	15
Diepoxide <sup>a</sup> (added) (approximately 1.5 gram diepoxide per 100 grams of propellant)	1.5 equivalents equivalent of AA

<sup>a</sup> Unox® Epoxide 221 - Trademark of Union Carbide Corporation, New York, New York.

(U) Details of the formulation are included, in some cases, by use of additional letters and numbers in the code name. The first number after the "103" corresponds to the copolymer formulation. For this report, the letter "E" will be used after the

**CONFIDENTIAL**

**CONFIDENTIAL**

copolymer formulation number to designate that the copolymer used in the propellant had been made by the incremental addition process. Numbers thereafter are batch numbers.

RH-Y-1 10. (C) geminal copolymer - vicinal plasticizer propellant (C)

(C) A propellant formulation identical to RH-SE-103 except that PPAA is replaced by PY.

RH-Y-2 11. (C) geminal copolymer - geminal plasticizer propellant (C)

(C) A propellant formulation similar to RH-SE-103 in which the vicinal materials have been replaced by geminal materials as follows:

Material	Wt. %
PY	13
TGAP	26
Ammonium Perchlorate	46
Aluminum	15
Diepoxide (added)	1.5 equivalents equivalent of AA

(U) The letters "G" and "V" in brackets distinguish between the geminal [G] and vicinal [V] materials. In those cases where both copolymer and plasticizer are used, the first letter refers to the copolymer and the second to the plasticizer.

**CONFIDENTIAL****Section III. (C) PHYSICAL PROPERTIES OF NF COMPOUNDS**

The two monomers and the two plasticizers are clear, colorless liquids at room temperature. The monomers each have sharp odors. Table I lists a few common physical properties. The infrared spectra of the materials are shown in Figures 1 and 2. Some viscosity values at various stages of propellant formulation are listed in Table II.

Table I. (C) Physical Properties of NF Materials (U)

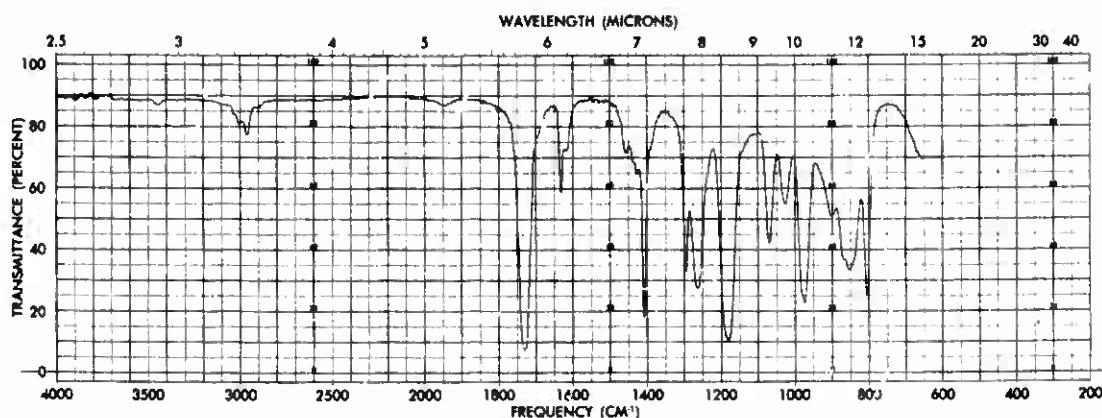
Property/Compound	Vic-NFPA	My [ G ]	TVOPA	TGAP
Density, g/cc at 25°C	1.350	1.325	1.54	1.458
Index of Refraction, $n_D^{20}$	1.4070	1.4012	1.3892	1.4031
Boiling Point, °C (torr)	43. (.3)	54°(4.2) 40° (2.4)		
Viscosity, Centipoise	2.7 (30°C) 3.5 (25°C)	2.0 (30°C)	32.4 (30°C)	51 (30°)

Table II. (C) Selected Viscosities at Various Stages of Formation(U)

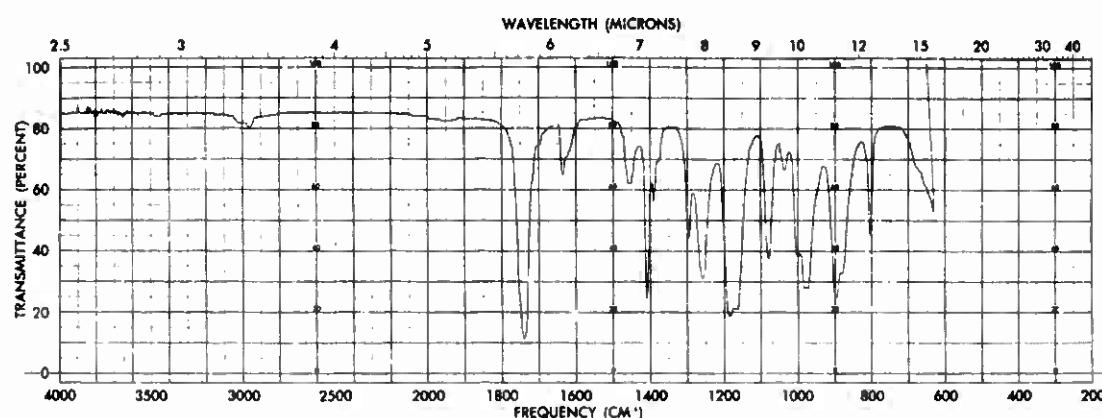
	Incremental Addition Copolymer, Vicinal	Batch Process Copolymer, Vicinal	Batch Process Copolymer, Geminal
<b>Polymer</b>			
Intrinsic Viscosity <sup>a</sup>	0.41	0.21	0.14
<b>Binder-TVOPA Plasticizer</b>			
Viscosity, Kp at 100°F	0.51	0.11	.09
<b>Propellant-TVOPA Plasticizer</b>			
Slurry Viscosity, Kp at 100°K	4.8	2.0	1.5

<sup>a</sup> In acetone solution at 30°C.

**CONFIDENTIAL**



2,3-Bis(difluoramino)propyl acrylate

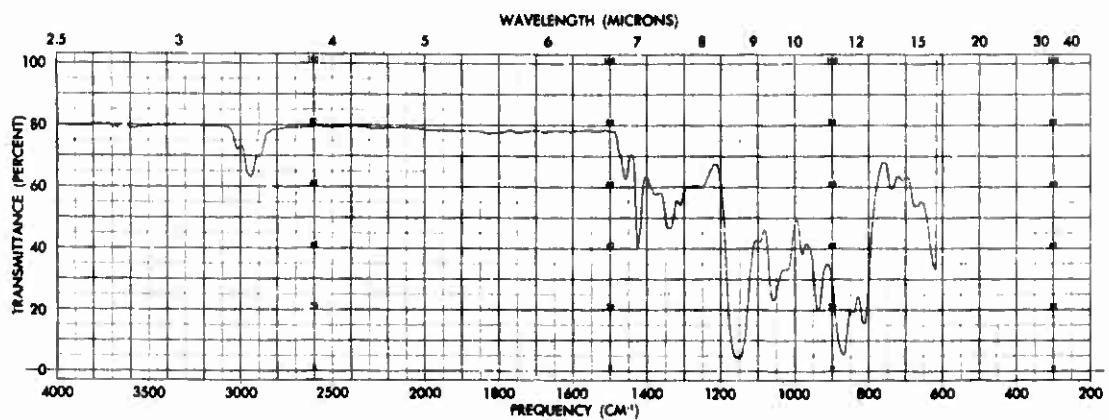


2,2-Bis(difluoramino)propyl acrylate

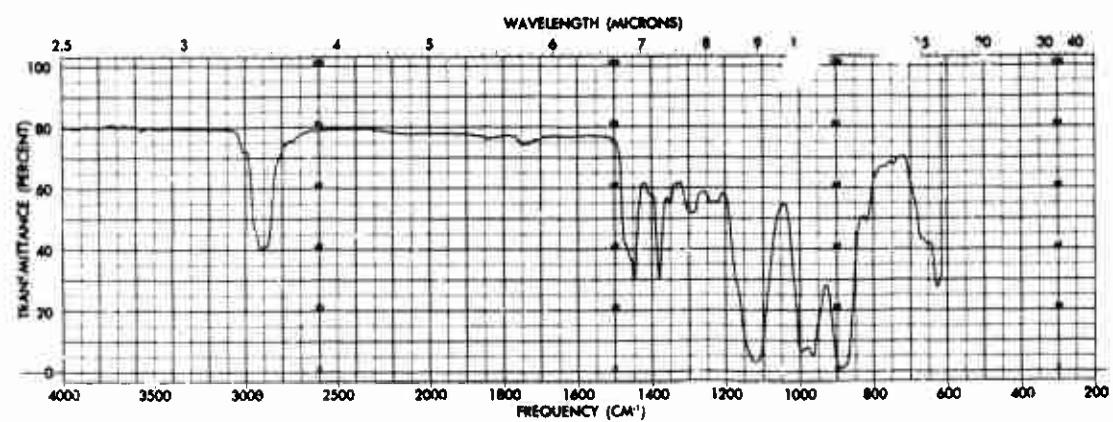
FIGURE 1. (C) INFRARED SPECTRA OF THE TWO MONOMERS (U)

**CONFIDENTIAL**

**CONFIDENTIAL**



1, 2, 3-Tris[1, 2-bis(difluoramino)ethoxy]propane



1, 2, 3-Tris[2, 2-bis(difluoramino)propoxy] propane

FIGURE 2, (C) INFRARED SPECTRA OF THE TWO PLASTICIZERS (U)

**CONFIDENTIAL**

#### Section IV. (U) GLASS-TRANSITION TEMPERATURE OF NF PLASTICIZERS AND POLYMERS

The glass-transition temperatures ( $T_g$ ) of the copolymers, plasticizers, and mixtures have been measured with a Perkin-Elmer Company Differential Scanning Calorimeter, Model DSC-1. The  $T_g$ 's were chosen from the experimental curves at the inflection points. For the calculated values, mixtures of the polymer-plasticizer pairs were made and the  $T_g$ 's measured. The  $T_g$  of the plasticizer was then calculated from the empirical equation (9)

$$1/T_{g(\text{mixture})} = w_1/T_{g(\text{polymer})} + w_2/T_{g(\text{plasticizer})}$$

where  $w_1$  and  $w_2$  are the weight percentages of polymer and plasticizer. The values of  $T_g$  are listed in Table III. The data show that the geminal polymer has a higher  $T_g$  than the vicinal polymer. The geminal polymer would therefore be expected to be somewhat inferior to the vicinal polymer insofar as low-temperature mechanical properties of a response nature are concerned. The  $T_g$ 's of the two plasticizers are very close, and the order reverses for measured and calculated values.

Table III. (U) Glass-Transition Temperatures of Geminal and Vicinal Materials

Materials	Measured $T_g$ , °C	Calculated $T_g$ , °C
poly- <u>vic</u> -NFPA (homopolymer)	-11	-
poly- <u>gem</u> -NFPA (homopolymer)	12	-
TVOPA [V]	-76	-80
TGAP [G]	-83	-75

## Section V. (U) MECHANICAL PROPERTIES OF NF PROPELLANTS

The mechanical properties, as measured by stress-strain experiments, have been measured at three different temperatures for the three propellant systems containing TVOPA as plasticizer. The data in Table IV, although favoring the incremental-addition process PPAA-4E (RH-SE-103-4E) and the geminal PY-1 (RH-Y-1) propellant binders, are not sufficiently different to allow a clear choice to be made. The number of variables in a propellant composition is sufficient to allow any of the binders tested to be used as far as mechanical properties are concerned.

Stress-strain properties of a propellant containing PY-1 and TCAP, RH-Y-2, have not yet been measured. However, equilibrium Young's moduli, E, have been measured for RH-SE-103 and RH-Y-2. The data were obtained using a simple beam-bending test at low rates of loading. The experimental technique consisted of centrally loading an end-supported beam of propellant (1/4-in. x 1/4-in. x 1 1/2-in.) in a device attached to an Instron universal tester. The data, Table V and Figure 3, show that RH-SE-103 enters the transition region (brittle range) at a lower temperature than does RH-Y-2. Hence, the failure properties of RH-SE-103 would be expected to be slightly superior in the low-temperature region to those of RH-Y-2.

Table IV. (U) Stress-Strain Data for Propellants <sup>a</sup>			
Propellant	Tensile Strength, psi		
	Elongation, %		
Propellant	-40° F	77° F	140° F
RH-SE-103-4E	646/24	90/33	63/27
RH-SE-103-4	364/20	61/33	40/30
RH-Y-1-4	563/26	71/30	49/27

<sup>a</sup> Rohm and Haas Company No. 2 tensile specimen at 2-in./min. crosshead.

\* Instron Corporation, Canton, Massachusetts.

Table V. (U) Equilibrium Young's Moduli for Propellants

Temperature, °K	Young's Modulus, E, psi	
	RH-SF-103	RH-Y-2-4
311	8.1	20.4
298	.	21.6
289	7.0	24.7
278	10.0	34.4
267	11.	47.9
255	16.0	219.5
244	46.4	332.5

**CONFIDENTIAL**

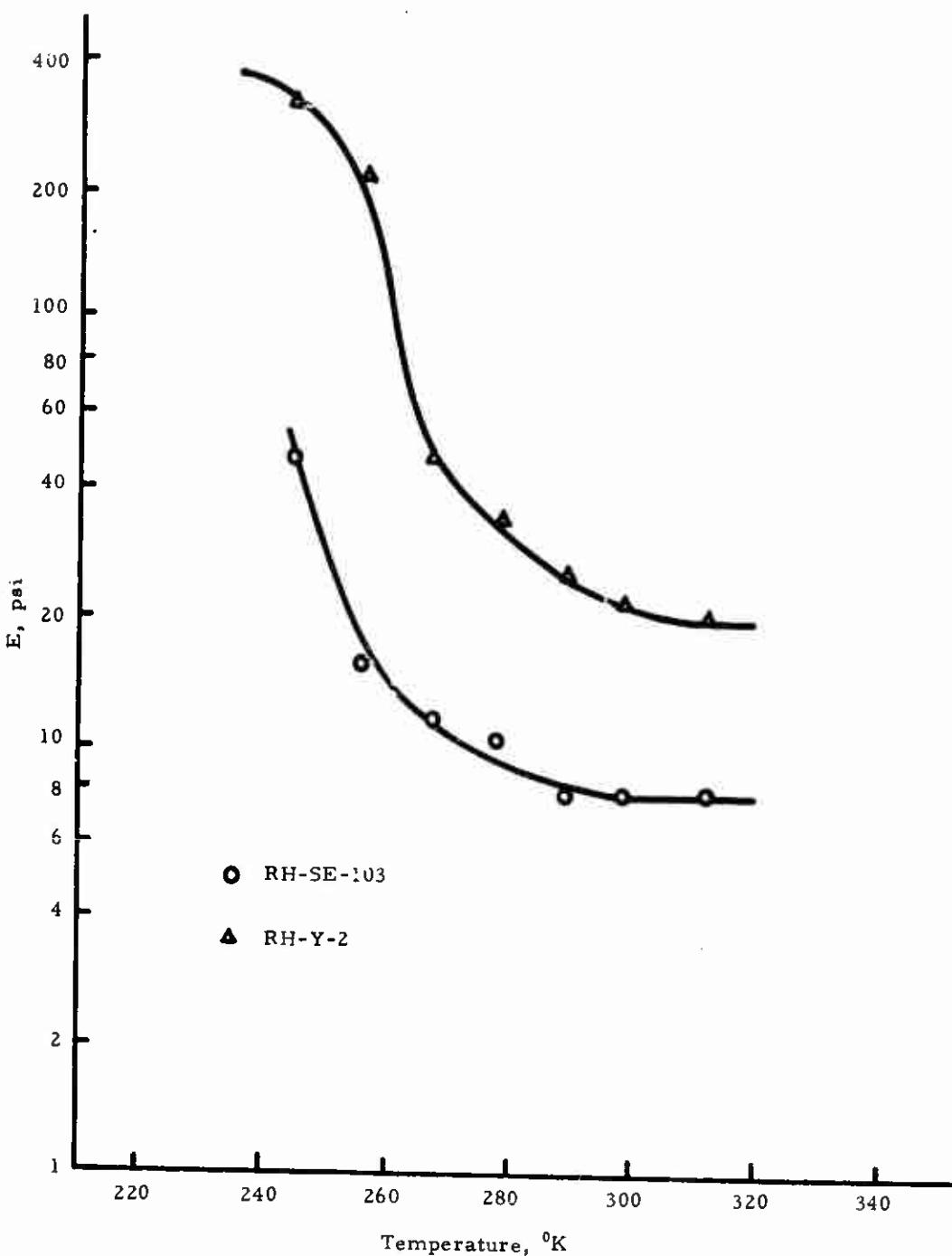


FIGURE 3. (C) EQUILIBRIUM YOUNG'S MODULI FOR RH-SE-103  
[V, V] AND RH-Y-2 [G, G]

**CONFIDENTIAL**

## Section VI. (U) FISSURING-TIME TEST

The fissuring-time test is used in these Laboratories as an accelerated aging test. The method and some early results are described in a previous report (11). The fissuring-time is a complex function of many variables in the propellant which is dependent on such things as 1) gas evolution rate, 2) gas diffusion rate, 3) type of gases evolved, and 4) mechanical properties of the binder. The results reported herein are for two-inch cubes heated at 80°C.

In the past few years the stability of RH-SE-103 [V, V] propellants, as measured by this test, has been greatly increased. Propellants now being made with batch-process copolymer PPAA-4 [V] have a fissuring time of 400 hours. This can be compared with early results when the fissuring times were of the order of 24 hours. The use of copolymer made by the newer incremental-addition process, PPAA-4E [V], has increased fissuring-times for propellant to more than 1500 hours. Values of this magnitude mean that the cube probably never will fissure and also that there is probably no auto-catalytic reaction which will ignite the sample. This lack of an auto-catalytic decomposition reaction in RH-SE-103 can be contrasted to the auto-catalytic decomposition of double-base propellants.

The propellant, RH-Y-1 [G, V] has a fissuring time in excess of 1500 hours and is still being tested. As yet, no tests have been made on propellant containing both geminal copolymer and geminal plasticizer. Changes in the test procedure, such as increased cube size, will be necessary to distinguish between propellants using PPAA-4E and those using PY-1.

## Section VII. (U) VACUUM GAS EVOLUTION

An important factor in the determination of the shelf life of a propellant is the amount of gas evolved by the propellant as a function of time. The vacuum gas evolution test, in which the amount of gas formed after 25, 50, and 150 hours of storage at 80°C is measured, is described in a previous report (11).

Data obtained from the copolymers, binders, and propellants discussed in this report, are contained in Table VI and illustrated in Figures 4, 5, and 6. The data show that vicinal copolymer made by the incremental-addition process, PPAA-4E, has a lower gas evolution rate than does the copolymer made by the batch process. This difference does not seem to be carried over significantly to the binders since after 150 hours the batch process binder evolved 1.10 cc of gas compared with 1.08 cc for the incremental-addition material. The geminal copolymer produced slightly more gas after 50 hours than did PPAA-4E, but after 150 hours the geminal material tested slightly better. In the binder, the improvement using the geminal copolymer was apparent after 25 hours and was quite significant at 150 hours.

The gas evolution was also less for those propellants in which PY-1 was used in place of PPAA, with at least a 100% improvement evident. The difference caused by replacing TVOPA [V] by TGAP [G] is not significant in the samples tested (RH-Y-1 [G,V] and RH-Y-2 [G-G]).

Table VI. (U) Gas Evolution of Selected Materials at 80°C in cc  
STP/gm

Copolymer			
	25 hrs.	50 hrs.	150 hrs.
PPAA-4 [ V ]	.44	.68	1.29
PPAA-4E [ V ]	.24	.45	.81
PY-1 [ G ]	.33	.56	.74
Binder			
	25 hrs.	50 hrs.	150 hrs.
PPAA-4 [ V ] + TVOPA-[ V ]	.36	.69	1.10
PPAA-4E-[ V ] + TVOPA-[ V ]	.28	.61	1.08
PY-1 [ G ] + TVOPA [ V ]	.16	.36	.63
Propellant			
	25 hrs.	50 hrs.	150 hrs.
RH-SE-103	.18	.37	.78
RH-Y-1 [ G, V ]	.11	.19	.35
RH-Y-2 [ G, G ]	.14	.22	.33

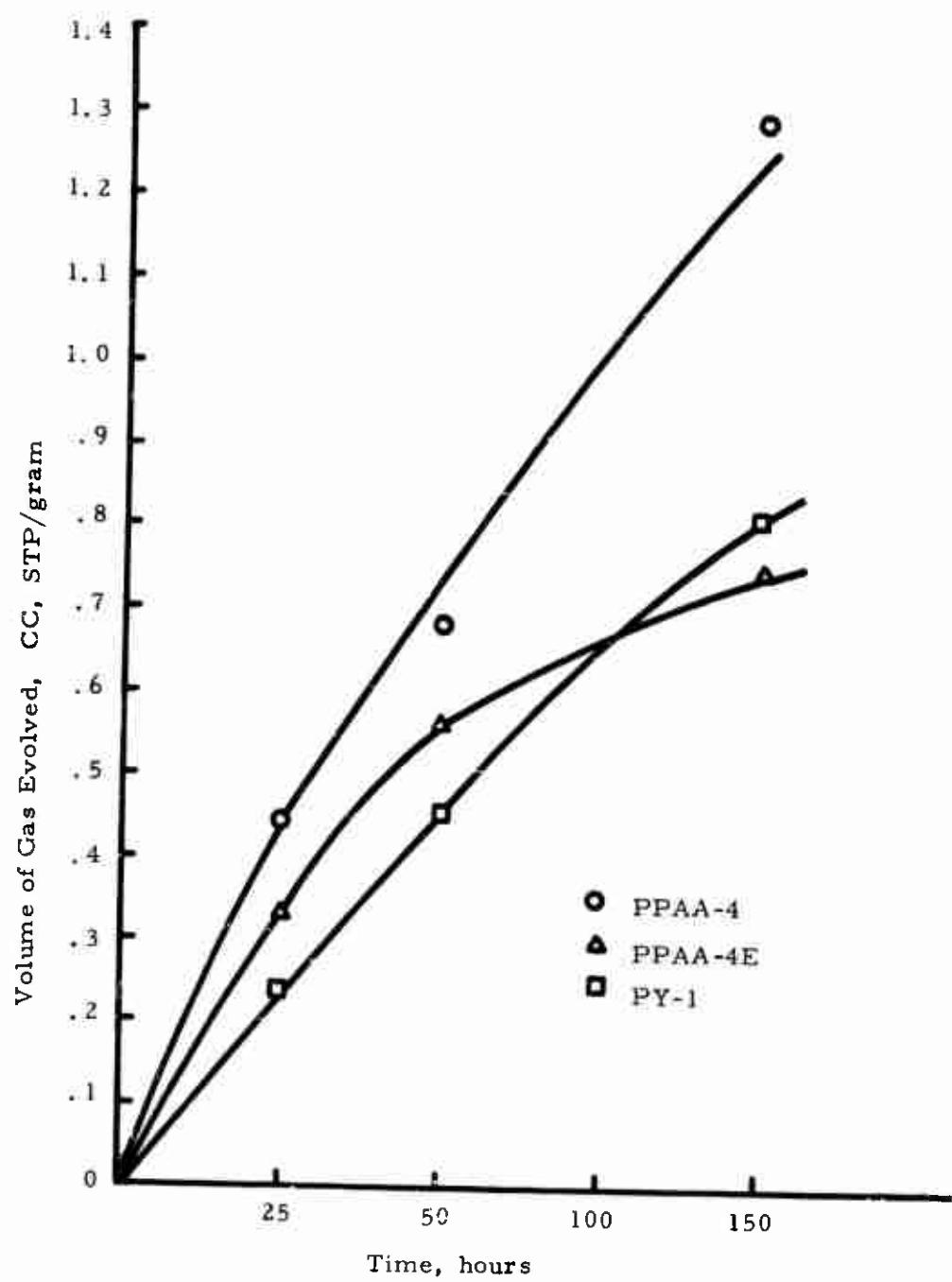


FIGURE 4. (U) GAS EVOLUTION OF NF COPOLYMERS

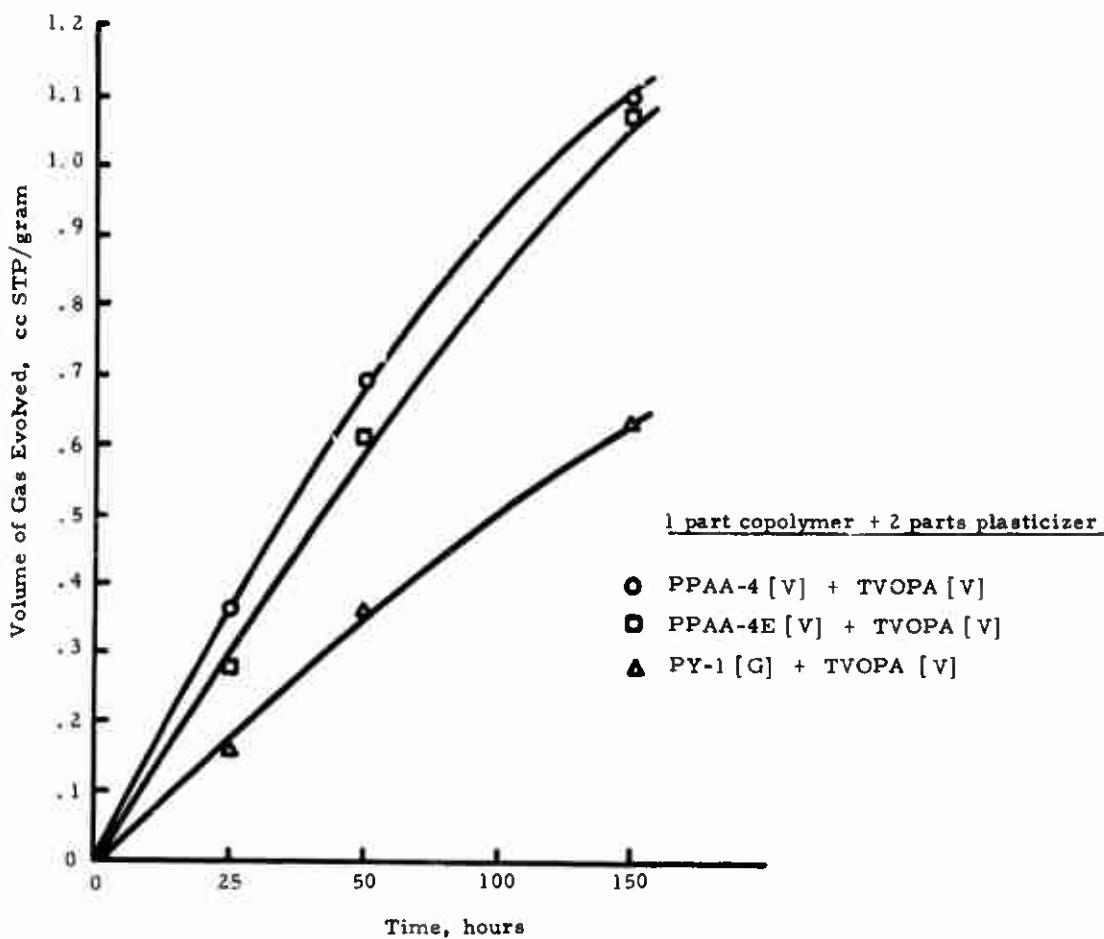


FIGURE 5. (U) GAS EVOLUTION OF SOME NF BINDERS

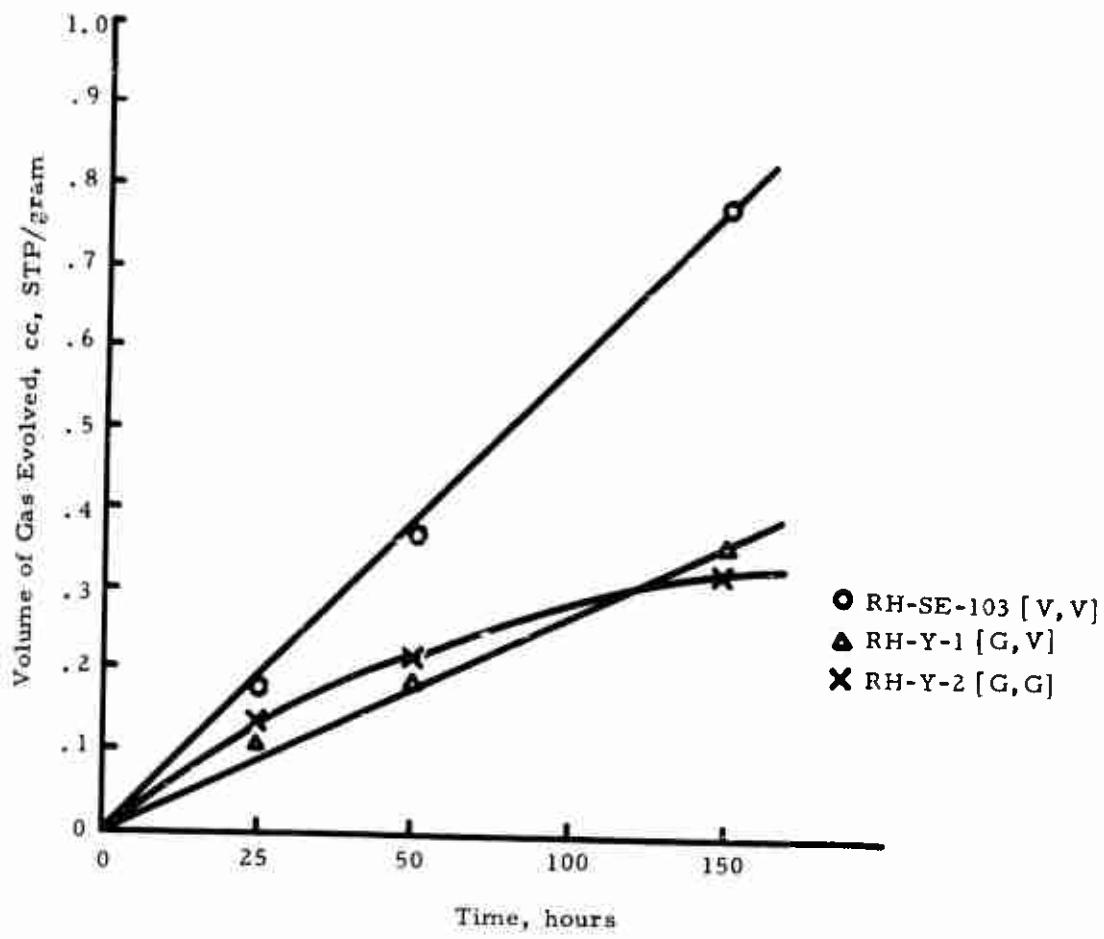


FIGURE 6. (U) GAS EVOLUTION OF THREE NF-CONTAINING PROPELLANTS

### Section VIII. (U) ADIABATIC SELF-HEATING RATE

The adiabatic self-heating rate (ASHR) tests have been used in our Laboratories as an accelerated aging test to evaluate new propellant formulations and ingredients and as a quality-control test. The apparatus (12) is essentially an adiabatically shielded oven assembly with associated control and measuring equipment. The sample is first heated to a given temperature, and then the oven is adiabatically controlled at the sample temperature so that, as the sample self-heats due to exothermic decomposition, the furnace temperature changes correspondingly. The use of this equipment as a quality-control instrument and as an aid in determining instabilities quickly will be described more fully in a forthcoming report (13).

The ASHR for geminal copolymer, PY-1, is very low, as expected. In fact, the rate is too low to be measured under the standard conditions adopted to test the vicinal materials. It was necessary to heat the sample to a starting temperature of  $160^{\circ}\text{C}$  instead of  $121^{\circ}\text{C}$  before decomposition started. Extrapolating the results to standard starting conditions, the rate is calculated to be less than  $0.1 \times 10^{-3}$  cal/gm-sec at  $143^{\circ}\text{C}$ , the standard reference temperature used for vicinal materials.

Recent batches of vicinal copolymers have had ASHR's of  $14 \times 10^{-3}$  (PPAA-4) and  $19 \times 10^{-3}$  cal/gm-sec (PPAA-3). These results are among the better ones for vicinal copolymers. Thus, the geminal copolymers (PY) have an ASHR about 150 times smaller than the better PPAA [V] now being produced at these Laboratories.

The binder systems containing two parts plasticizer to one part copolymer have also been studied using both types of copolymers together with TVOPA [V]. The average values of the ASHR's of binders using vicinal made by different methods and with different ratios of NFPA [V] to AA range from  $2.5 \pm 1.3 \times 10^{-3}$  to  $3.8 \pm 1.4 \times 10^{-3}$  cal/gm-sec. The binders using geminal copolymer containing 4% AA and TVOPA [V] plasticizer have had ASHR's of  $1.6 \pm 0.4 \times 10^{-3}$  cal/gm-sec. Thus, in the binders, the replacement of the vicinal copolymer (PPAA) with the geminal copolymer (PY-1) has reduced the ASHR of the binder even when two-thirds of the binder is still a vicinal material. Also, the variations from sample to sample are much smaller for the geminal material than for the vicinal material. The effect of the geminal plasticizer, TGAP, on the ASHR of the binder remains to be seen.

Propellant samples differing only in type of copolymer have also been tested. The ASHR for RH-SE-103 was  $1.6 \times 10^{-3}$  cal/gm-sec. The corresponding propellant, RH-Y-1-7001 [G, V] made with PY-1 [G], had a rate of  $1.0 \times 10^{-3}$  cal/gm-sec, showing that the improvement in ASHR noted in the binder is carried over into the propellant. We can only speculate now on the effect which would be obtained if the vicinal plasticizer, TVOPA, were replaced by a geminal plasticizer such as TGAP.

The data presented in this section are tabulated in Table VII. For illustration two ASHR curves, one for PPAA-4 [V] and one for PY-1 [G] are shown in Figure 7.

Table VII. (U) Adiabatic Self-Heating Rates of Propellant Materials

Material	Rate at $143^{\circ}\text{C} \times 10^3$ , cal/gm-sec
Copolymers	
PPAA-4 [V]	14.
PPAA-3 [V]	19.
PY-1 [G]	{ nil from $121^{\circ}\text{C}$ nil from $138^{\circ}\text{C}$ 0.1 from $160^{\circ}\text{C}$
Binders (1 part copolymer + 2 parts plasticizer)	
PPAA-3 [V] + TVOPA [V]	$3.8 \pm 1.4$
PPAA-4E [V] + TVOPA [V]	$2.5 \pm 1.3$
PY-1 [G] + TVOPA [V]	$1.6 \pm 0.4$
Propellants	
RH-SE-103-1149 [V, V]	1.6
RH-Y-1-7001 [G, V]	$1.0 \pm 0.1$

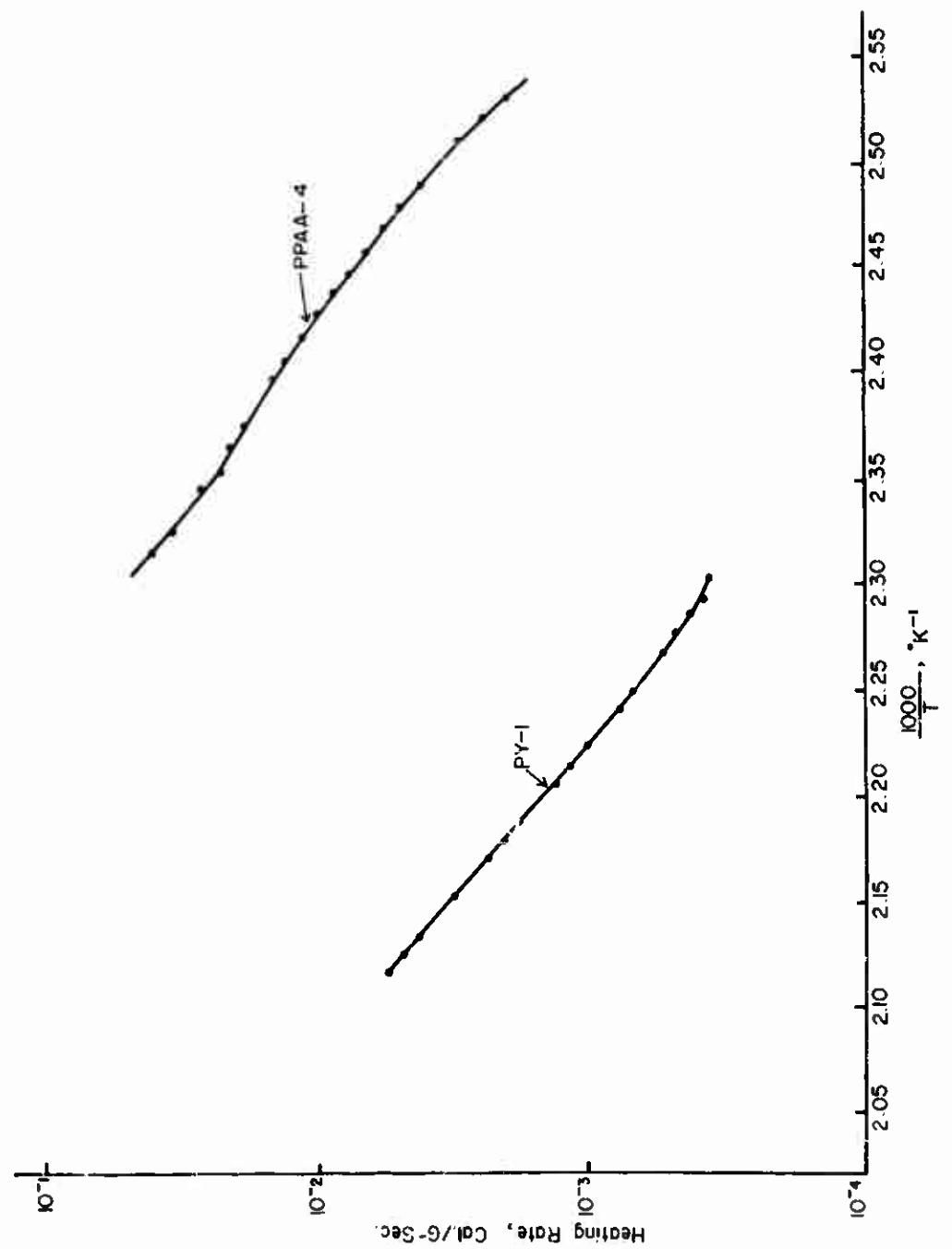


FIGURE 7. (U) ADIABATIC SELF-HEATING RATES FOR PPAA-4  
[V] AND PY-1 [G]

## Section IX. (U) DIFFERENTIAL THERMAL ANALYSIS

Differential thermal analysis (DTA) has been performed on the geminal and vicinal compounds, on combinations of them, and on propellants. The apparatus used in these Laboratories has been described by Scroggins (14). The measurements reported here have been made at a scan rate of  $10^{\circ}\text{C}/\text{min}$  with a nominal sample size of 20 milligrams. With this large size, the samples frequently ignite or even explode instead of slowly decomposing to give a simple exothermic peak. The temperatures reported herein, unless otherwise stated, are the reference temperatures corresponding to peak deflection of the samples. Figures 8 through 11 are representative of the data obtained and illustrate the peak temperatures listed in Table VIII. These values are representative of those obtained for our current "better" samples, both from the pilot plant and the laboratory.

The thermograms for the monomers are of some special interest since they show the polymerization exotherms. For vicinal NFPA, the polymerization exotherm peaks at  $169^{\circ}\text{C}$ , being a fairly large peak (Figure 10). The major exotherm then occurs at  $232^{\circ}\text{C}$ . The thermogram for MY [G] is shown in Figure 11. The bulk polymerization exotherm is first noted at about  $160^{\circ}\text{C}$ . Before polymerization can proceed very far, the material begins to boil so that the boiling endotherm overcomes the polymerization exotherm. From the thermogram, the normal boiling point of MY is estimated to be about  $180^{\circ}\text{C}$ . The small amount of material that is polymerized has a peak exotherm temperature of  $264^{\circ}\text{C}$ .

According to the data in Table VIII, the geminal copolymer is more stable than the vicinal copolymer and this increased stability is carried over into the propellant. The plasticizers, TVOPA [V] and TGAP [G], have approximately the same peak DTA temperatures, although it should be noted that, in all cases, GAP samples have violently ignited at the peaks.

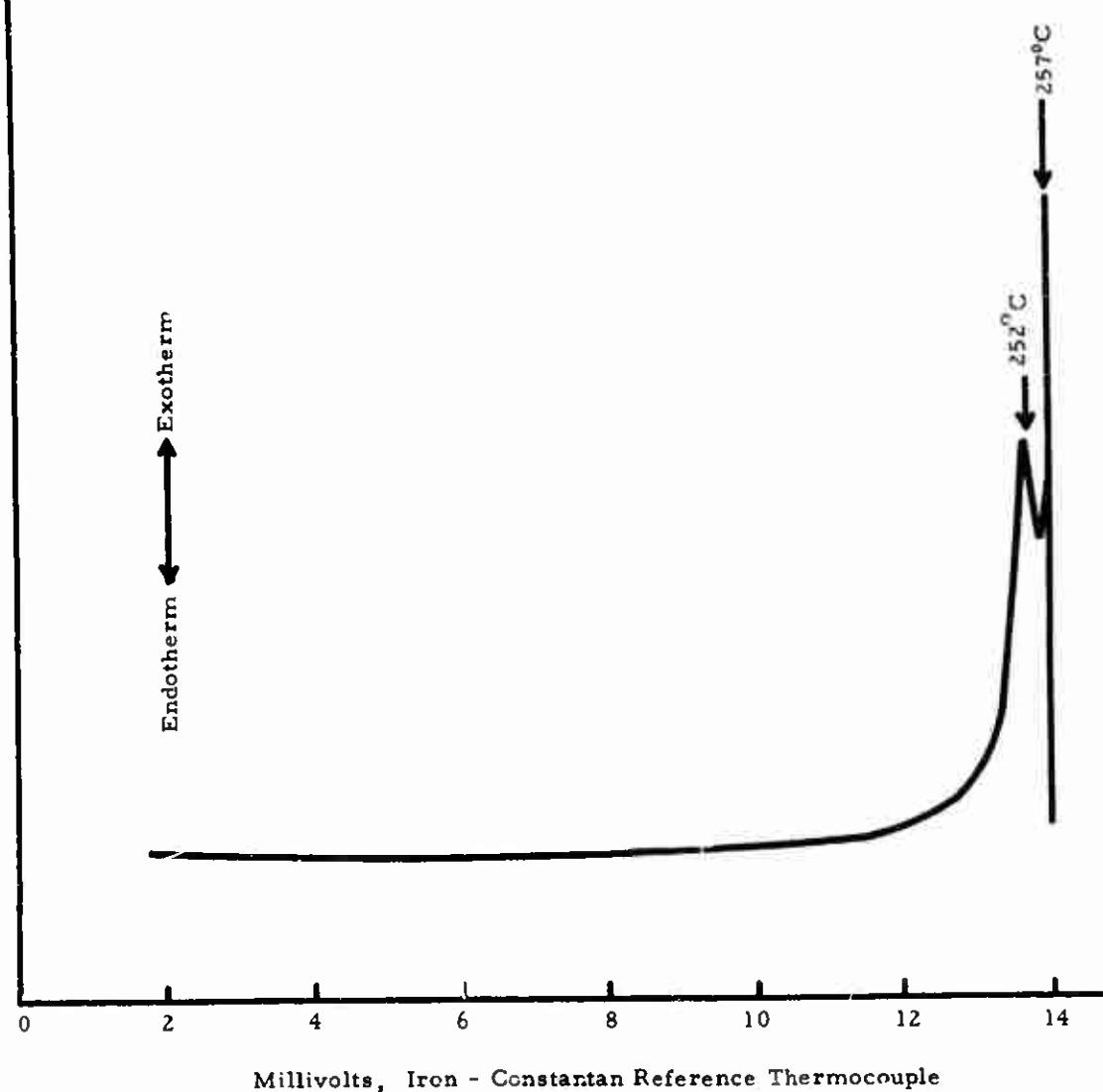


FIGURE 8. (U) THERMOGRAM OF TGAP [ G ]

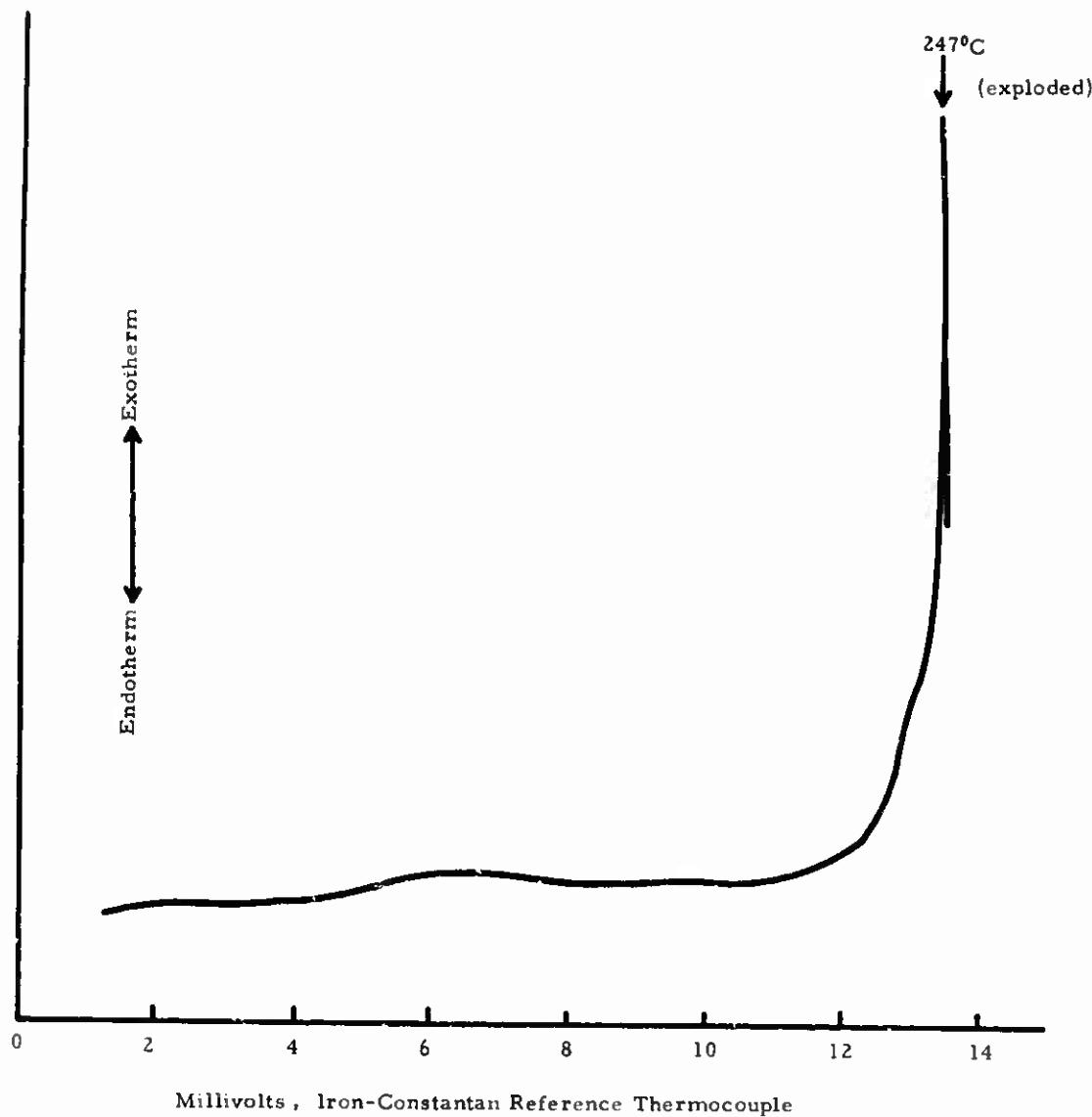


FIGURE 9. (U) THERMOGRAM OF RH-Y-2 [G,G] PROPELLANT

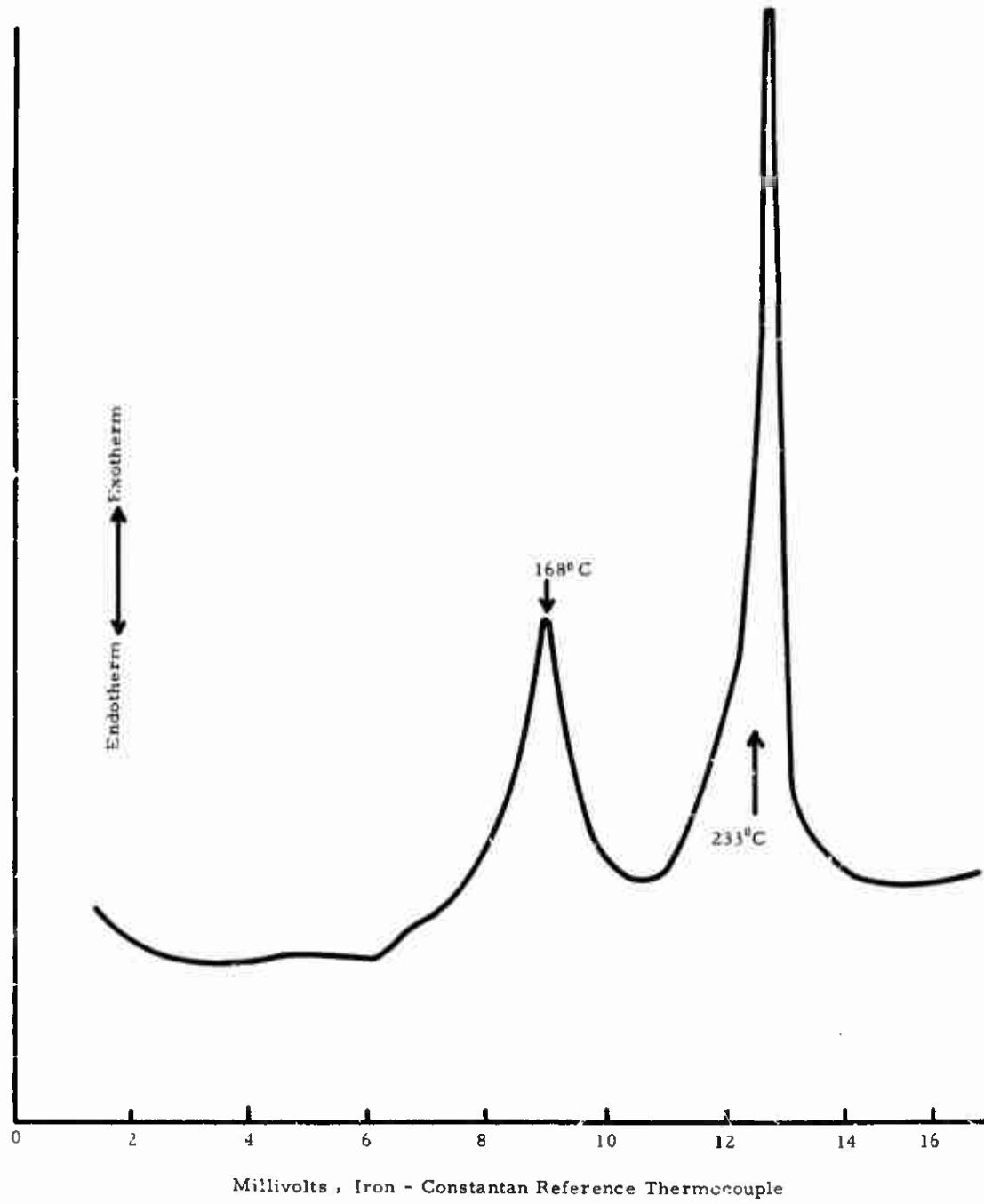


FIGURE 10. (U) THERMOGRAM OF NFPA [ V ]

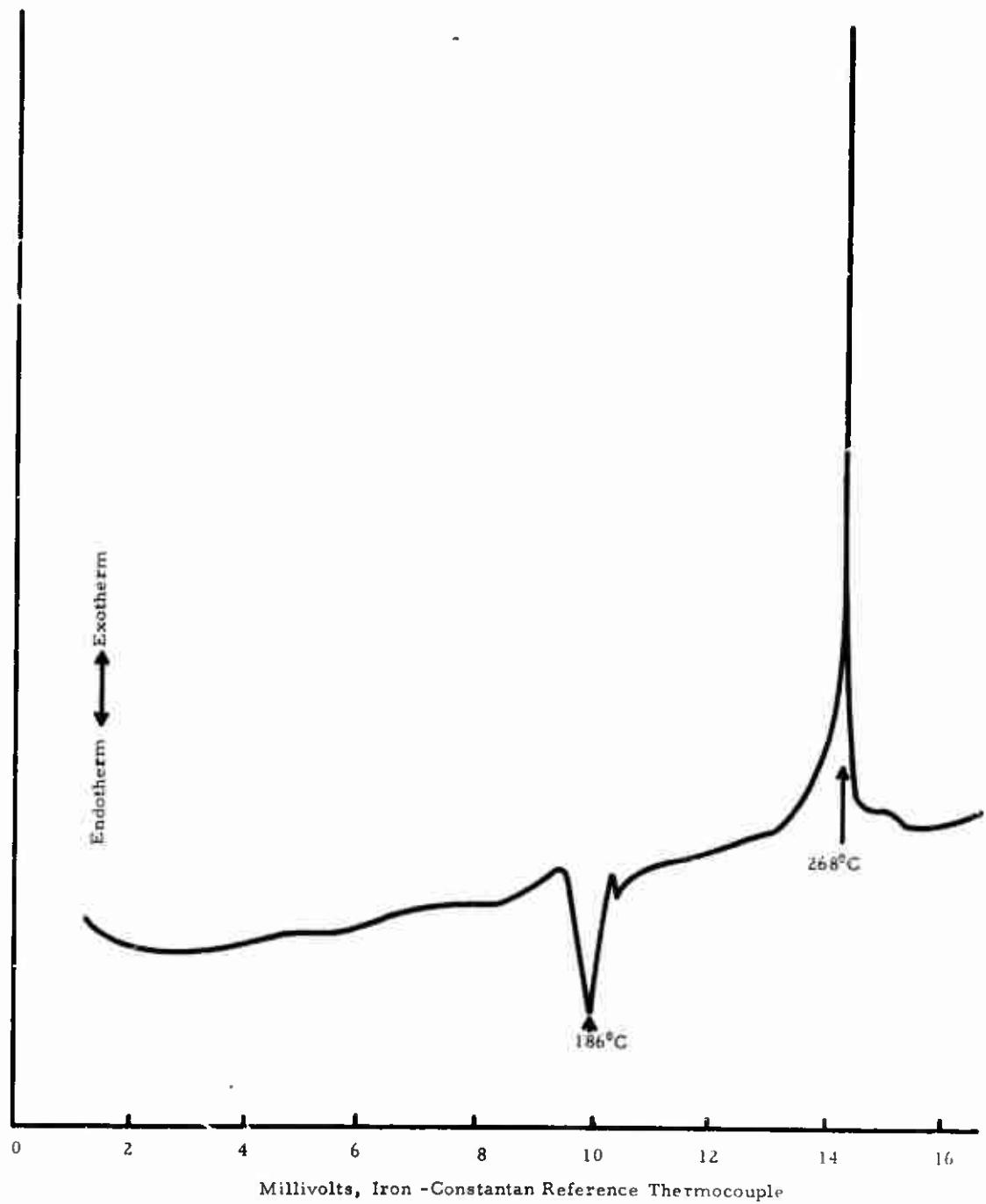


FIGURE 11. (U) THERMOGRAM OF MY [G]

Table VIII. (U) DTA Temperatures for Vicinal and Geminal Materials

Material	Peak Exotherm Temperature, °C	Comments
Vicinal		
TVOPA	270	
NFPA (monomer)	232	polymerization exotherm peak at 170°
homopolymer of NFPA	244	
PPAA-4	218	
PPAA-4E	215	
TVOPA/PPAA-4 (2/1)	208	ignition at peak
RH-SE-103	240	ignition at peak
Geminal		
TGAP	256	ignition at peak - shoulder peak ~ 252°
MY (monomer)	261	endotherm overlapping exotherm peaking at 185
homopolymer of MY	255	ignition at peak, shoulder peak ~ 245
PY-1	255	ignition at peak
TGAP/homopolymer of MY (2/1)	256	ignition at peak
TGAP/PY-1 (2/1)	252	ignition at peak
RH-Y-2	247	ignition at peak
Geminal and Vicinal		
TVOPA/PY (2/1) (V/G)	218	ignition at peak
RH-Y-1 (G, V)	248	

**CONFIDENTIAL**

Section X. (C) THERMOGRAVIMETRIC ANALYSIS<sup>a</sup> (U)

Thermogravimetric analyses (TGA) were performed with a Cahn RG Electrobalance, and F & M Model 240 temperature programmer, a Moseley Model 7000A XY recorder, and accessory equipment. The experiments were carried out in air with a heating rate of 10°C/min. Two TGA graphs are shown in Figures 12 and 13.

The TGA's of the various polymers studied were very similar. Each showed a slight weight loss before entering the rapid decomposition range and then exploded, leaving a small amount of black residue in the sample pan and elsewhere in the system. The relation of the ignition temperatures to each other in these experiments is similar to those of the peak temperatures in the DTA experiments (Table IX).

The TGA's of the propellants were also very similar. All showed a slow rate of weight loss starting at about 100°C. The samples that burned out showed the same order of stability as that indicated by DTA. Samples of RH-Y-1 and RH-Y-2 occasionally exploded instead of burning out (Table IX).

---

<sup>a</sup> These experiments were performed at the Army Propulsion Laboratory and Center by Mr. James Burnett through the courtesy of Mr. Chester Huskins.

**CONFIDENTIAL**

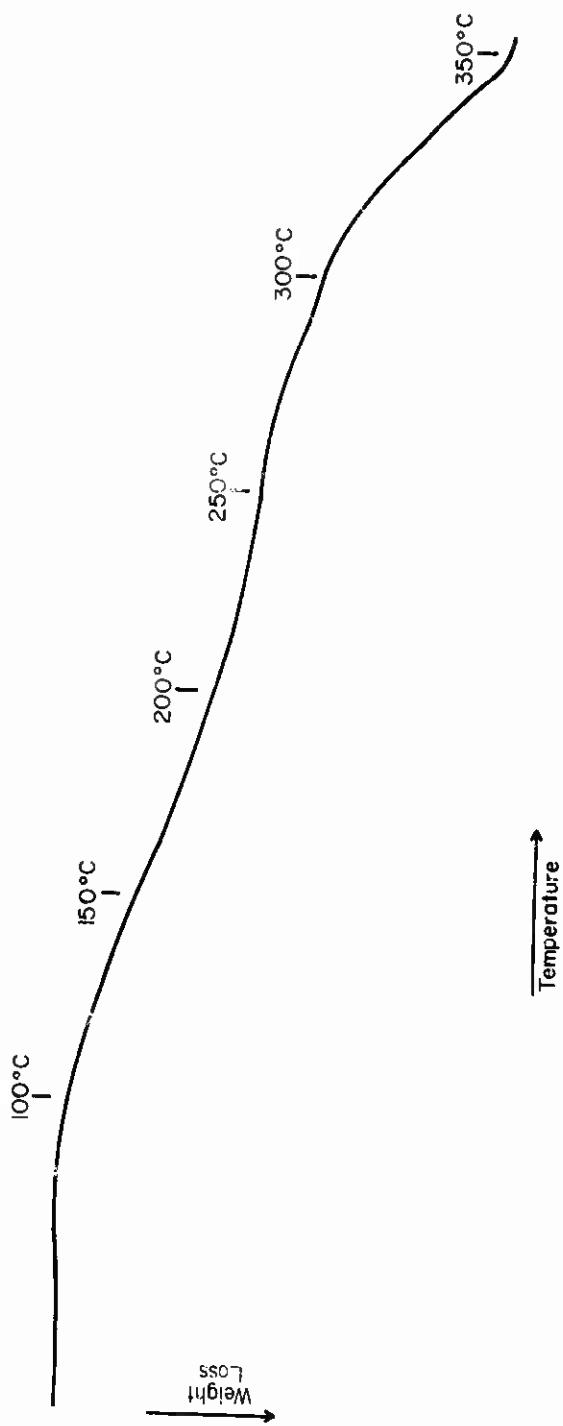


FIGURE 12. (U) THERMOGRAVIMETRIC ANALYSIS CURVE FOR  
RH-SE-103 [ V, V ]

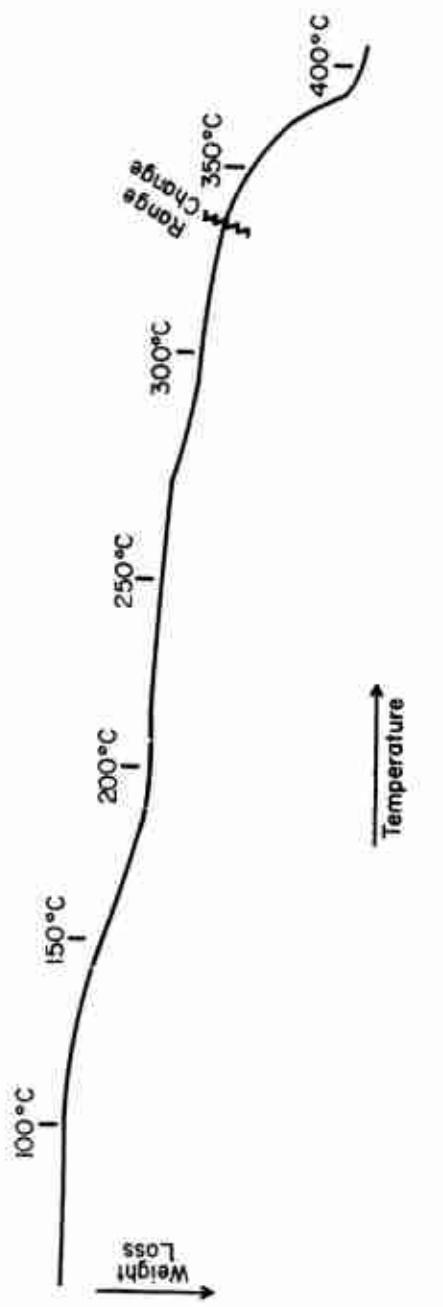


FIGURE 13. (U) THERMOGRAVIMETRIC ANALYSIS CURVE FOR  
RH-Y-1 [G, V]

**CONFIDENTIAL**

Table IX. (C) TGA Data for Geminal and Vicinal Comparison

Polymers			
Material	Ignition Temperature °C		
poly- <u>vic</u> -NFPA (lab homopolymer)	240		
PPAA-4-1015 (plant copolymer) [ V ]	220		
poly- <u>gem</u> -NFPA (lab homopolymer)	266		
PY-1 (lab copolymer) [ G ]	270		
PY-1-7003 (plant copolymer) [ G ]	255		
Propellants			
Material	Temperature °C beginning of wt. loss	Temperature °C 2nd wt. loss start	Comments
RH-SE-103 [ V-V ]	100	300	350°C burned out
RH-Y-1 [ G-V ]	100		235°C exploded
RH-Y-1 [ G-V ]	100	280	{ burned out above 350°C
RH-Y-2 [ V-V ]	100		
RH-Y-2 [ V-V ]	100		231°C exploded 370°C burned out

**CONFIDENTIAL**

**CONFIDENTIAL****Section XI. (C) SENSITIVITY**

Sensitivities for both vicinal and geminal ingredients are measured by tests at various stages of processing. The impact test is performed on a Picatinny type of impact tester; the card-gap test is of standard design. These tests have been described in a previous report by Pratt (15). Pratt's report also contains data for other tests for the vicinal materials. His report will be updated shortly (16).

The comparison data are shown in Table X. The impact data show that the geminal materials are more sensitive than the corresponding vicinal materials. The few figures available for the card-gap test show no significant difference.

Table X. (C) Comparison of Sensitivity Data of Geminal and Vicinal Materials

	Impact, Kg-in.	Card-Gap, in.
MY [G]	7.7 - 9.84	-
NFPA [V]	> 38	-
TGAP [G]	3	-
TVOPA [V]	7 - 14	-
PY-1 [G]	7.7	-
PPAA-4 [V]	21	-
PY-1 [G] solution	> 38	-
PPAA-4 [V]	> 38	-
PY-1 + TVOPA [G-V]	5.66	.42 - .44
PY-1 + TGAP [G-G]	(1.6)? 6.24	-
PPAA-4 + TVOPA [V-V]	10.1	.44 - .46
RH-SE-103 [V, V]	8.09	-
RH-Y-1 [G, V]	5.44	-
RH-Y-2 [G, G]	4.9	-
RH-SE-103 slurry	-	1.21 - 1.23
RH-Y-1 slurry	-	1.20 - 1.22

**CONFIDENTIAL**

Section XII. (C) BALLISTIC PROPERTIES

Strand burning rates have been measured for both binders and cured propellant by means of a strand burner described previously (17). In addition, some rates have been measured in a micro-window bomb.

At each pressure studied, the burning rates of the binders having geminal components are faster than those for the all-vicinal binders, at the same ratio of plasticizer to copolymer. At 1000 psig the rates are as follows:

TGAP/PY-1 (2/1) [ G/G ]	- 1.35 in./sec
TVOPA/PY-1 (2/1) [ V/G ]	- .8 in./sec
TVOPA/PPAA-4 (2/1) [ V/V ]	- .6 in./sec

The data are shown in Figure 14. The percentage increase from all-vicinal binder to all-geminal is considerably more than 100%.

The strand burning rates for the propellants also show the increased burning rates noted in the binders obtained by replacing the vicinal NF<sub>2</sub>'s with corresponding geminal-NF<sub>2</sub>'s at the higher pressures, but the increase is much smaller. In fact, the increase in rate is of little value and may safely be ignored. Current data with the geminal system at lower pressures (below 2000 psig) are somewhat ambiguous on the relative rates of RH-Y-1 [ G-V ] and RH-Y-2 [ G-G ]. From the strand burner, there is not enough data to locate positively the pressure-burning rate curves, and it may be that the curves for these two propellants actually cross near 1000 psig. Additional data for RH-Y-1 [ G-G ] are available for the low-pressure region. These points are below the high-pressure points extrapolated from the other apparatus and do not clarify the issue. In any case, both geminal-containing propellants have slightly higher burning rates than does RH-SE-103 [ V-V ]. The data are collected in Table XI and illustrated in Figure 15. The propellants used in this part of the study were identical in all respects except for the replacement of the vicinal materials by geminal materials on a weight-by-weight basis.

Data have also been obtained from small motor firings for propellant containing geminal copolymer<sup>a</sup>. The results of these firings are listed in Table XII together with data for propellants containing the vicinal copolymers made by the two different production

---

<sup>a</sup> Rohm and Haas Company unpublished data.

**CONFIDENTIAL**

methods. Here again, the burning rate of the geminal propellant is higher than that for the vicinal propellant. The measured impulse is somewhat less for the geminal and the pressure coefficient is between the two values reported for the two vicinal systems.

Table XI. (C) Strand Burning Rates for Propellants

RH-SE-103 [ V-V ]		RH-Y-1 [ G-V ]		RH-Y-2 [ G-G ]	
K <sub>psig</sub>	r <sub>b</sub> in./sec	K <sub>psig</sub>	r <sub>b</sub> in./sec	K <sub>psig</sub>	r <sub>b</sub> in./sec
0.96	1.10	1.05	1.35	0.55 <sup>a</sup>	0.92
1.52	1.43	1.69	1.81	1.09	1.14
2.33	1.96	4.06	3.85	1.15 <sup>a</sup>	1.31
4.32	3.37	6.49	5.84	1.65 <sup>a</sup>	1.72
6.65	5.07	11.9	9.89	2.08	2.38
13.2	8.90	18.1	13.5	2.15 <sup>a</sup>	2.02
17.4	11.3			4.45	4.81
				9.28	9.75
				17.3	15.5

<sup>a</sup> Data from Polymer Chemistry Group strand burner, others from Ballistics Section burner.

Table XII. (C) Ballistic Data Comparing Geminal- and Vicinal-Copolymer Propellants

Propellant, type copolymer			
Property	Incremental-Addition Vicinal	Batch Vicinal	Batch Geminal
Impulse	258.5	256.8	255.2
R <sub>1000</sub> , in./sec	1.14	1.10	1.26
n	0.51	0.60	0.55

**CONFIDENTIAL**

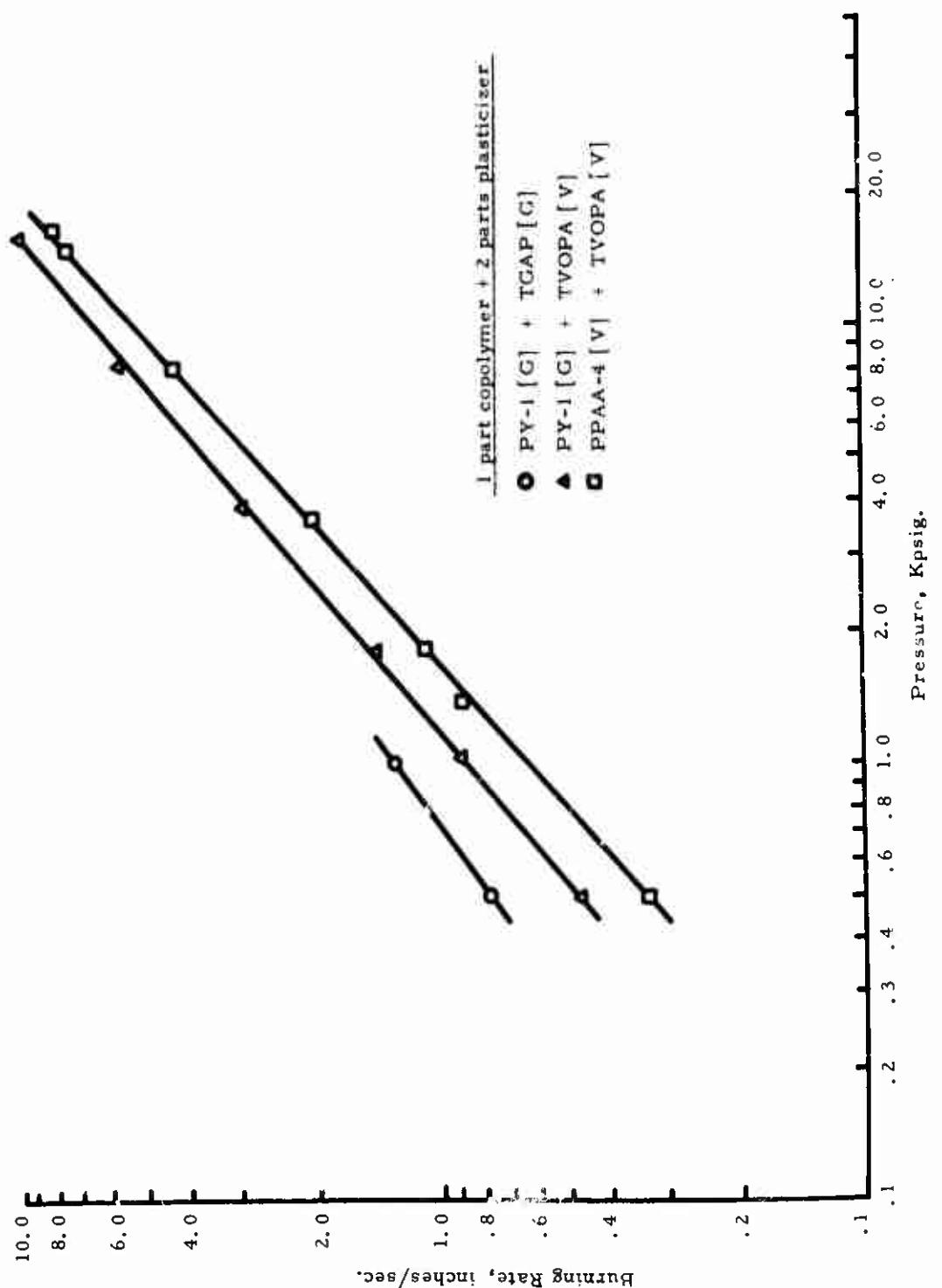


FIGURE 14. (C) STRAND BURNING RATES OF BINDERS (U;

**CONFIDENTIAL**

**CONFIDENTIAL**

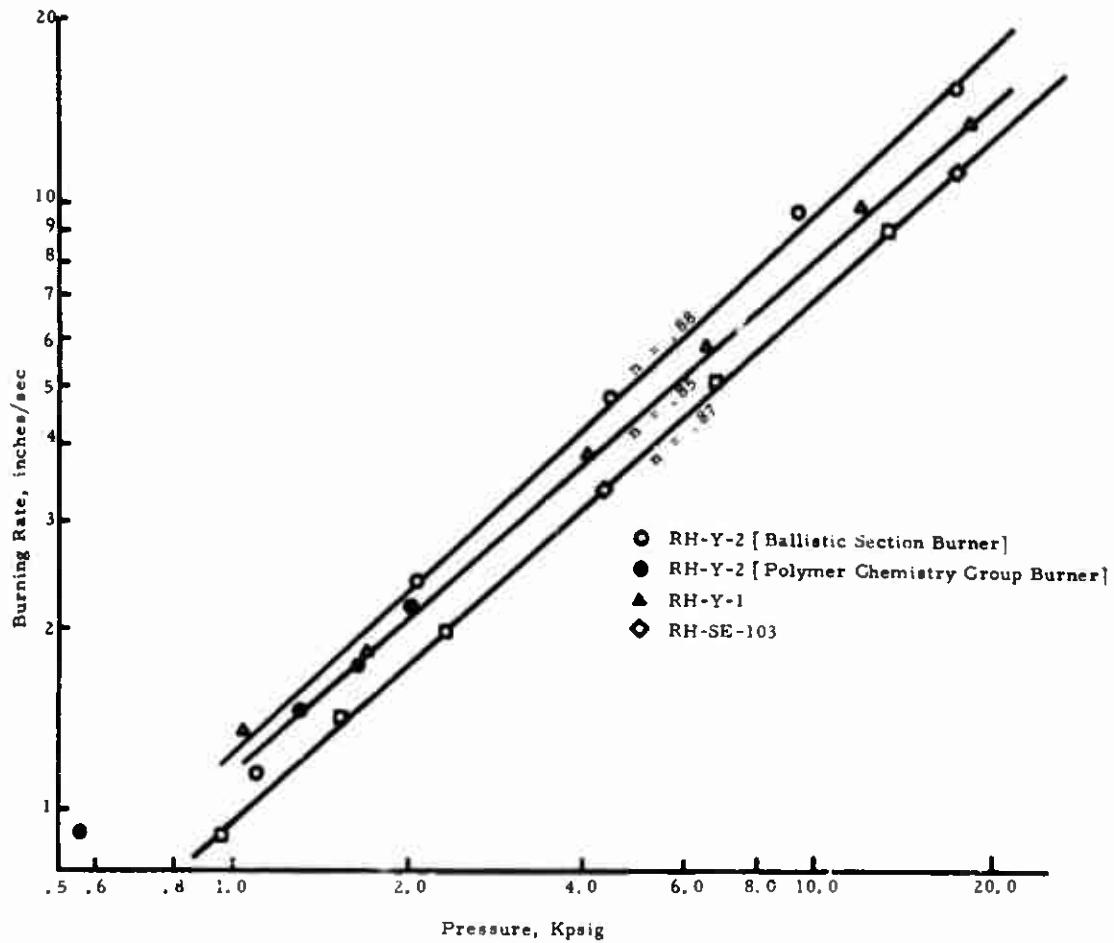


FIGURE 15. (C) STRAND BURNING RATES FOR THREE  
NF-CONTAINING PROPELLANTS (U)

**CONFIDENTIAL**

**CONFIDENTIAL**

### Section XIII. (C) SUMMARY AND CONCLUSIONS

For the properties discussed, the geminal materials studied compare favorably with their vicinal counterparts. A major drawback with the geminal materials is their increased impact sensitivity. However, card-gap, DTA, and TGA tests do not show a greater sensitivity for the geminal materials; in fact, DTA and TGA show the geminal materials, other than the plasticizer, to be more stable thermally than the corresponding vicinal materials. The burning rate increases obtained by replacing the vicinal materials with geminal, although very large in the binders themselves, are small in the propellants and do not constitute a significant improvement.

The area in which the use of the geminal materials was predicated to offer an improvement was in those factors leading to improved shelf life. The tests dealing most directly with shelf-life (the adiabatic self-heating rate tests, vacuum gas evolution tests, and fissuring-time tests) show the geminal materials to be as good as and, in some cases, much better than the best of the vicinal materials made to date.

The next area for study should be the evaluation of the all-geminal binders and propellants by the adiabatic self-heat rate test and a more stringent fissuring-time test. At the same time, the smaller range of values for the ASHR of the geminal materials compared with the vicinal materials should be checked to see if these values indicate that it is easier to produce "good" geminal material than to produce "good" vicinal material.

**CONFIDENTIAL**

**CONFIDENTIAL**

**(C) REFERENCES**

1. Rohm and Haas Company, Huntsville, Alabama, Unpublished results.
2. Rohm and Haas Company, Huntsville, Alabama, ANALYTICAL CHEMISTRY OF N-F COMPOUNDS (U), Keith Booman, Presented and published in the bulletin of the 17th Meeting of the JANAF Panel on Analytical Chemistry of Solid Propellants, October 1961 (Confidential). SPIA/AC-17, pp. 113/24.
3. Rohm and Haas Company, Huntsville, Alabama, THE PROPERTIES OF A NEW ACRYLIC MONOMER (U), K. Johnson, 8 July 1966, Report S-103, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contract DA-01-021 AMC-11536 (Z) (Confidential). AD-373-785.
4. Rohm and Haas Company, Huntsville, Alabama, Report S-105, to be published.
5. Rohm and Haas Company, Huntsville, Alabama, NFPA-ACRYLIC ACID COPOLYMERIZATION CHARACTERISTICS AND PROCESS DEVELOPMENT (U), D. A. Willoughby, June 1967, Report S-114, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contract DA-01-021 AMC-11536 (Z) (Confidential). AD-381-719.
6. Rohm and Haas Company, Huntsville, Alabama, SCALE-UP OF N<sub>2</sub>F<sub>4</sub>-OLEFIN REACTIONS IN A HIGH PRESSURE LIQUID PHASE FLOW REACTOR (C), Tom Dwyer, 3 December 1965, Report S-83, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contracts DA-01-021 AMC-11536 (Z) and DA-01-021 ORD-11909 (Mod. 6) (Confidential). AD-367-626.
7. Rohm and Haas Company, Huntsville, Alabama, DEVELOPMENT OF A PRACTICAL PROCESS FOR THE PREPARATION OF GEM-DIFLUORAMINO COMPOUNDS. THE DIFLUORO-SULFAMIC ACID REAGENT (U), R. D. Shoultz, 1 May, 1967, Report S-129, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contracts DA-01-021 AMC-11536 (Z) and DAAH01-67-C-0655 (Confidential). AD-380-719.
8. Rohm and Haas Company, Huntsville, Alabama, Report to be published.

9. Rohm and Haas Company, Huntsville, Alabama, INGREDIENTS FOR ADVANCED PROPELLANTS (U), Staff of Chemistry Section, 3 April, 1967, Report S-131, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contracts DA-01-021 AMC-11536 (Z) and DAAH01-67-C-0655 (Confidential).AD-380-062.
10. Miller, M. L., THE STRUCTURE OF POLYMERS, New York, Rheinhold Publishing Corporation, 1966, p. 290.
11. Rohm and Haas Company, Huntsville, Alabama, PREPARATION AND CHARACTERIZATION OF NF PREPOLYMER PROPELLANTS (U), M. G. Baldwin, 7 October 1965, Report S-88, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contract DA-01-021 AMC-11536 (Z) (Confidential).AD-366-148.
12. Rohm and Haas Company, Huntsville, Alabama, DEVELOPMENT OF AN ADIABATIC CALORIMETER (U), E. L. Allen, 6 December 1966, Report S-65, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contracts DA-01-021 ORD-11878 (Z) and DA-01-021 AMC-11536 (Z) (Unclassified). AD-803-483.
13. Rohm and Haas Company, Huntsville, Alabama, E. L. Allen, Report to be published.
14. Rohm and Haas Company, Huntsville, Alabama, APPLICATION OF DTA TO THE THERMAL DECOMPOSITION OF PROPELLANT AND PROPELLANT INGREDIENTS (U), K. G. Scroggins, 30 June, 1965, Report S-61, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contract DA-01-021 ORD-11909 (Z) (Confidential). AD-364-082.
15. Rohm and Haas Company, Huntsville, Alabama, THE EXPLOSIVE CHARACTERISTICS OF NF COMPOUNDS AND EXPLOSIVES (U), T. Pratt, 8 October 1965, Report S-79, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contracts DA-01-021 ORD-11878 (Z), DA-01-021 ORD-11909 (Z) and DA-01-021 AMC-11536 (Z) (Confidential).AD-366-209.
16. Rohm and Haas Company, Huntsville, Alabama, T. Pratt, to be published.
17. Rohm and Haas Company, Huntsville, Alabama, BURNING RATES OF SOLID COMPOSITE PROPELLANTS AT PRESSURES UP TO 20,000 PSIG (U), R. B. Cole, 15 September 1966, Report S-80, U. S. Army Missile Command, Redstone Arsenal, Alabama, Contract DA-01-021 ORD-11909 (Z) (Confidential). AD-375-636.

**CONFIDENTIAL**

DOCUMENT CNTROL DATA - R & D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)		
1. ORIGINATING ACTIVITY (Corporate author) Rohm and Haas Company Redstone Research Laboratories Huntsville, Alabama 35807		2a. REPORT SECURITY CLASSIFICATION Confidential
2b. GROUP 4		
3. REPORT TITLE A Comparison of Selected Geminal and Vicinal Ingredients for Use in Propellants (U)		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)		
5. AUTHOR(S) (First name, middle initial, last name) J. A. Lovinger		
6. REPORT DATE September 1967	7a. TOTAL NO. OF PAGES 40	7b. NO. OF REFS 17
8a. CONTRACT OR GRANT NO. DAAH01-67-C-0655	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Report S-151	
b. PROJECT NO.		
c.	sd. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.		
10. DISTRIBUTION STATEMENT Initial distribution of this report has been made in accordance with contractual agreements. Qualified users may obtain from Defense Documentation Center.		
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Research and Development Directorate U. S. Army Missile Command Redstone Arsenal, Alabama 35809	
13. ABSTRACT (C) This report contains a compilation of data comparing geminal and vicinal difluoramino-containing plasticizers and copolymers. The plasticizers studied are 1, 2, 3-tris[1,2-bis(difluoramino)ethoxy]propane and 1, 2, 3-tris[2,2-bis(difluoramino)propoxy]propane. The copolymers are acrylic acid copolymers of both 2, 3-bis(difluoramino)propyl acrylate and 2, 2-bis(difluoramino)propyl acrylate. Data are presented for the monomeric materials, copolymers, binders, and propellants.		
The data indicate that the vicinal and geminal materials behave similarly in many respects. The major disadvantage of the geminal NF-containing materials is their greater impact sensitivity. The main area in which the geminal materials show an advantage is seen in those tests related to storage stability. These tests include vacuum gas evolution and adiabatic self-heating. Data on fissuring time show that the geminal copolymers are as good as, if not better than, the best vicinal copolymers made to date. The geminals also have higher burning rates than the corresponding vicinals; however, the increase observed in the propellant is small.		

DD FORM 1473 1 NOV 66  
REPLACES DD FORM 1473, 1 JAN 64, WHICH IS  
OBSOLETE FOR ARMY USE.**CONFIDENTIAL**

**CONFIDENTIAL**

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Difluoramino plasticizers and copolymers						
TVOPA						
TGAP						
<u>gem</u> -NFPA						
<u>vic</u> -NFPA						
Tg						
Fissuring-time tests						
Vacuum gas evolution						
Adiabatic self-heating						
DTA						
TGA						
Sensitivity						
Impact Stability						
Burning rate						
Mechanical properties						
Physical properties						

**CONFIDENTIAL**